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Personal Weather Station Hint
Absolute and Relative Atmospheric Pressure

The objective of this presentation is to :

- RECAP what causes atmospheric pressure, how pressure varies with height and the factors affecting pressure;
- EXAMINE the pressure readings available on many home weather stations (relative and absolute pressure);
- DETERMINE the methods to set up the pressure readings on the home weather station.

By Mark Little

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What Does Absolute & Relative Pressure Mean?

Most personal weather stations that I have come across that provide two pressure measurements use the follow terms (or similar) in relation to their pressure measurements:

(1) ABSOLUTE PRESSURE. This is taken to mean the actual atmospheric pressure read by the weather station. That is, the atmospheric pressure at the height of the barometer.

(2) RELATIVE PRESSURE. This is taken to be the estimated atmospheric pressure at Mean Sea Level (MSL), based on the atmospheric pressure at the current height. Personal weather stations that provide this measurement require the user to provide the difference in pressure between the height of the weather station and the MSL. If you are above MSL, the MSL pressure will be higher, if you are below MSL, the MSL pressure will be lower.

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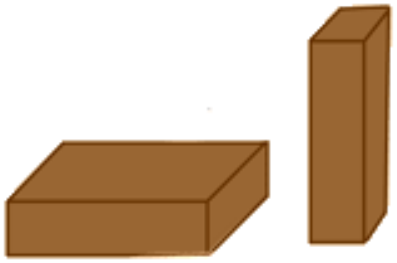
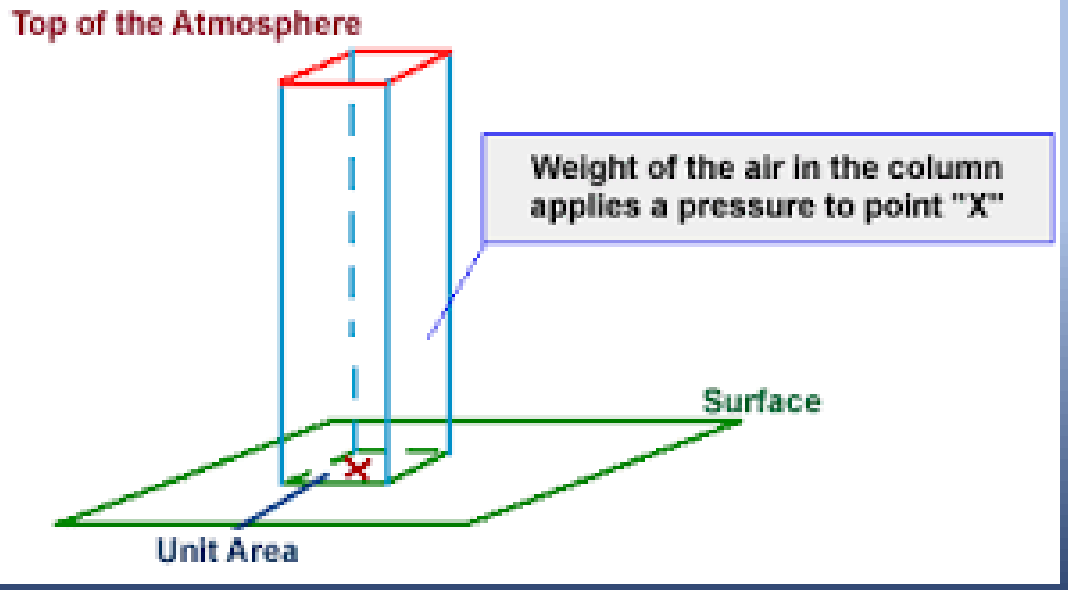
What Causes Atmospheric Pressure?

$$Pressure = \frac{Force}{Area} = \frac{F}{A}$$





- The air above any point weighs down upon it as a result of the force of the Earth's gravity.
- Atmospheric Pressure is the weight of the atmosphere divided by the size of area.
- The higher the area is above sea level, the less atmosphere there is above the area, so the pressure is less than at sea level.
- The higher the temperature, the more the molecules bounce around, so the molecules move further apart, so there are fewer molecules above the unit area, so the pressure is lower.

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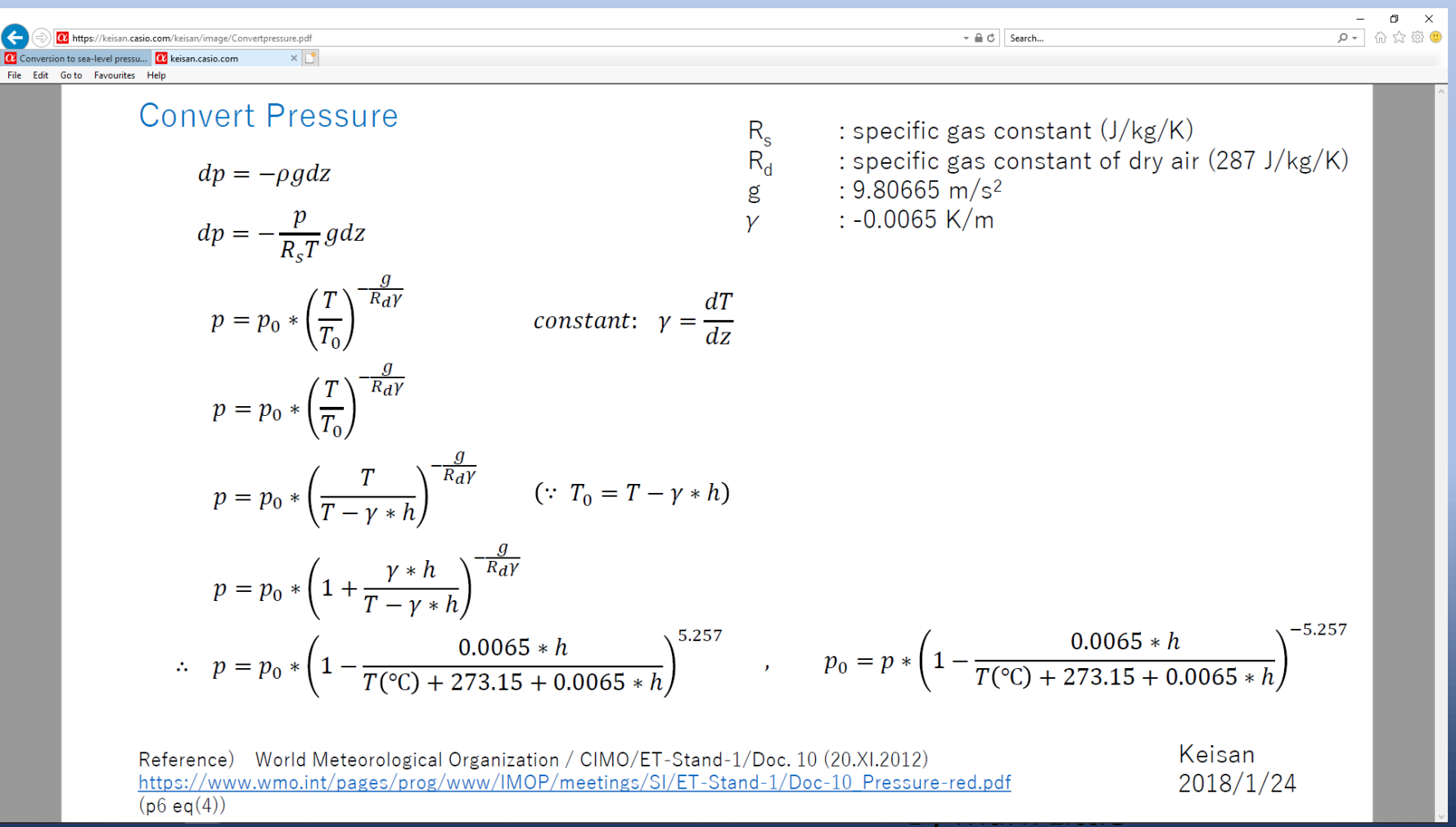
Calculating Equivalent MSL Pressure



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Conversion to sea-level pressu... | keisan.casio.com

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Convert Pressure

R_s : specific gas constant (J/kg/K)
R_d : specific gas constant of dry air (287 J/kg/K)
g : 9.80665 m/s^2
γ : -0.0065 K/m

$$dp = -\rho g dz$$

$$dp = -\frac{p}{R_s T} g dz$$

$$p = p_0 * \left(\frac{T}{T_0}\right)^{-\frac{g}{R_d \gamma}} \qquad constant: \quad \gamma = \frac{dT}{dz}$$

$$p = p_0 * \left(\frac{T}{T_0}\right)^{-\frac{g}{R_d \gamma}}$$

$$p = p_0 * \left(\frac{T}{T - \gamma * h}\right)^{-\frac{g}{R_d \gamma}} \qquad (\because \ T_0 = T - \gamma * h)$$

$$p = p_0 * \left(1 + \frac{\gamma * h}{T - \gamma * h}\right)^{-\frac{g}{R_d \gamma}}$$

$$\therefore \quad p = p_0 * \left(1 - \frac{0.0065 * h}{T(℃) + 273.15 + 0.0065 * h}\right)^{5.257} \quad , \quad p_0 = p * \left(1 - \frac{0.0065 * h}{T(℃) + 273.15 + 0.0065 * h}\right)^{-5.257}$$

Reference) World Meteorological Organization / CIMO/ET-Stand-1/Doc. 10 (20.XI.2012)
https://www.wmo.int/pages/prog/www/IMOP/meetings/SI/ET-Stand-1/Doc-10_Pressure-red.pdf
(p6 eq(4))

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Here is the derivation of the equation used to determine the Mean Sea Level (MSL) Pressure, if you are keen to see how it was derived, but we will just use the formula for this exercise. ☺

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Calculating the MSL Pressure Difference

- The two main parameters that can change the atmospheric pressure in a static column of air are:
  - The temperature of the air; and
  - The height above the base of the column of the air.

- The ground level temperature in South Australia can range from about -8°C (Yongala, 1976) to 50.7°C (Oodnadatta, 1960)

- Given that the majority of the Earth is covered by the oceans, in most cases, the Mean Sea Level (MSL) is taken as the base of the atmospheric column. About ⅓ of the world population less than 100 vertical metres above MSL. For Australia, about 80% of the population live within close proximity to the coastline.

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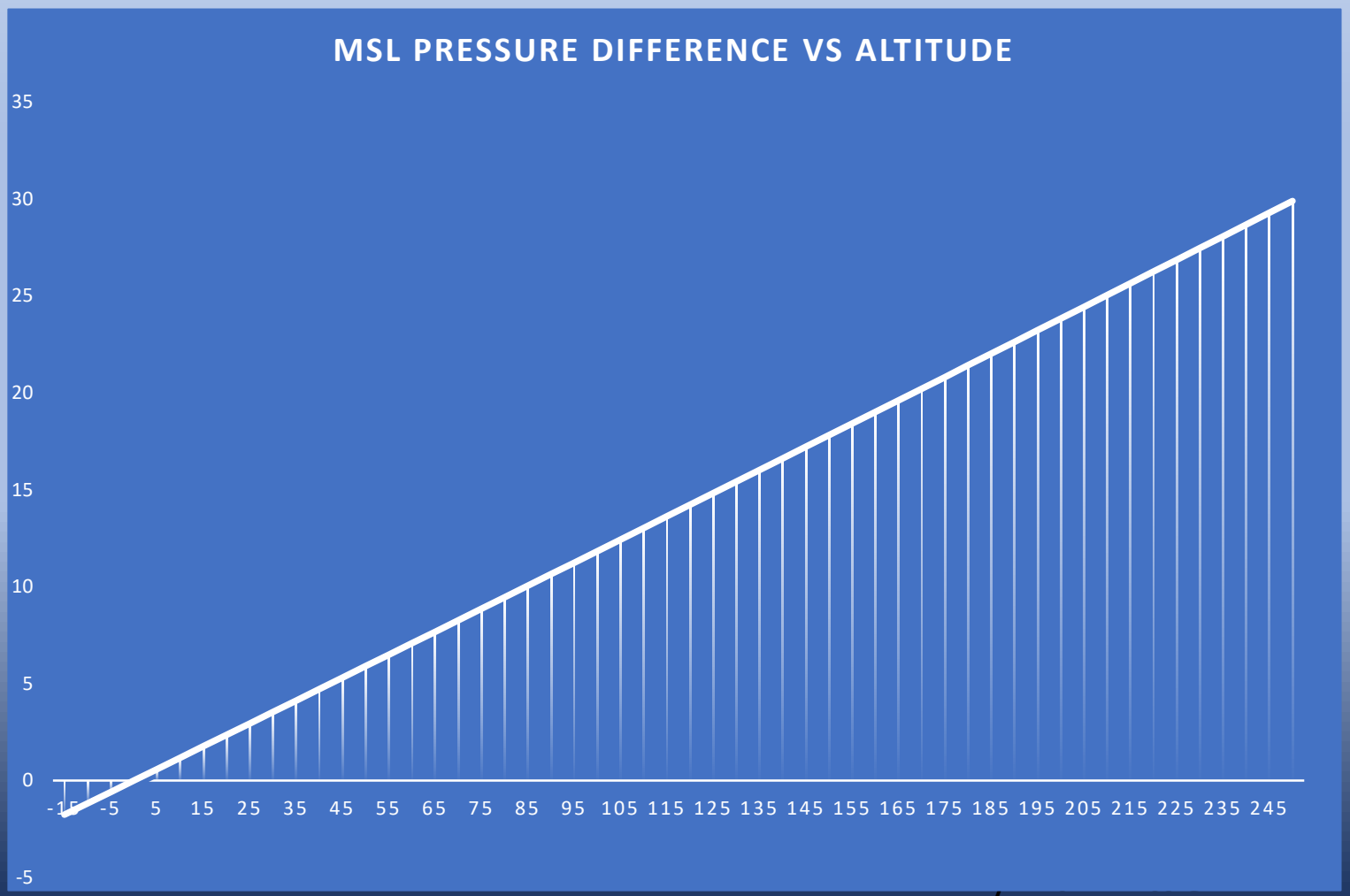
Change in MSL Vs Measurement Altitude



This example uses the average Mean Sea Level (MSL) as the pressure being measured by the weather station and the average temperature of 15 degrees Celsius.

Pressure = 1013.25 hpa
Temperature = 15°C

The Vertical Y-Axis is the increase in pressure (hPa) at MSL. The Horizontal X-Axis is the weather station height above MSL in metres.

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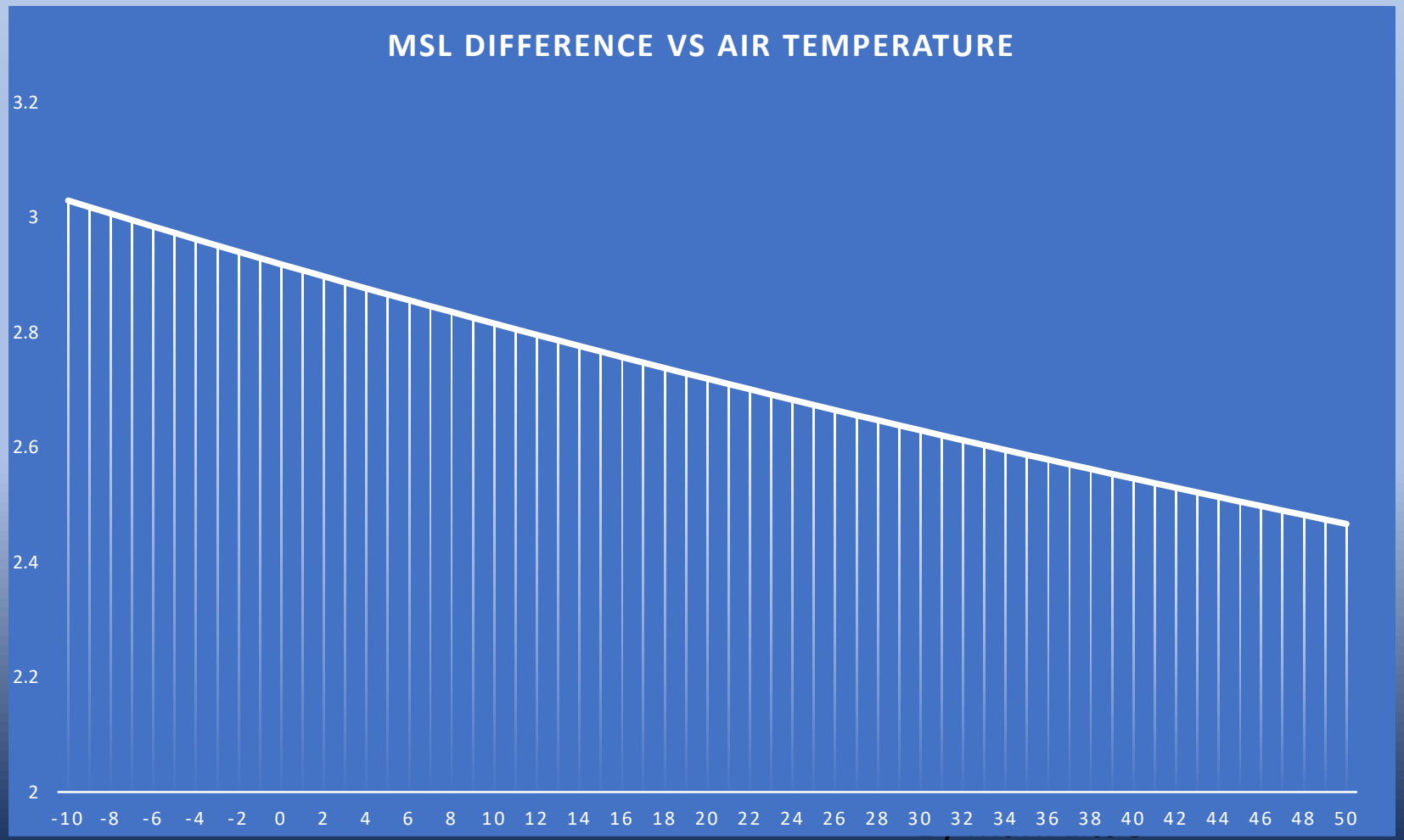
Change in MSL Vs Air Temperature



The graph takes an average atmospheric pressure and the height of my weather station above Mean Sea Level (MSL).

Height above MSL = 23 metres
Measured Pressure = 1013.25 hPa

The Y-Axis is the calculated increase in pressure at MSL (hPa). The X-Axis is the weather station air temperature in Celsius.

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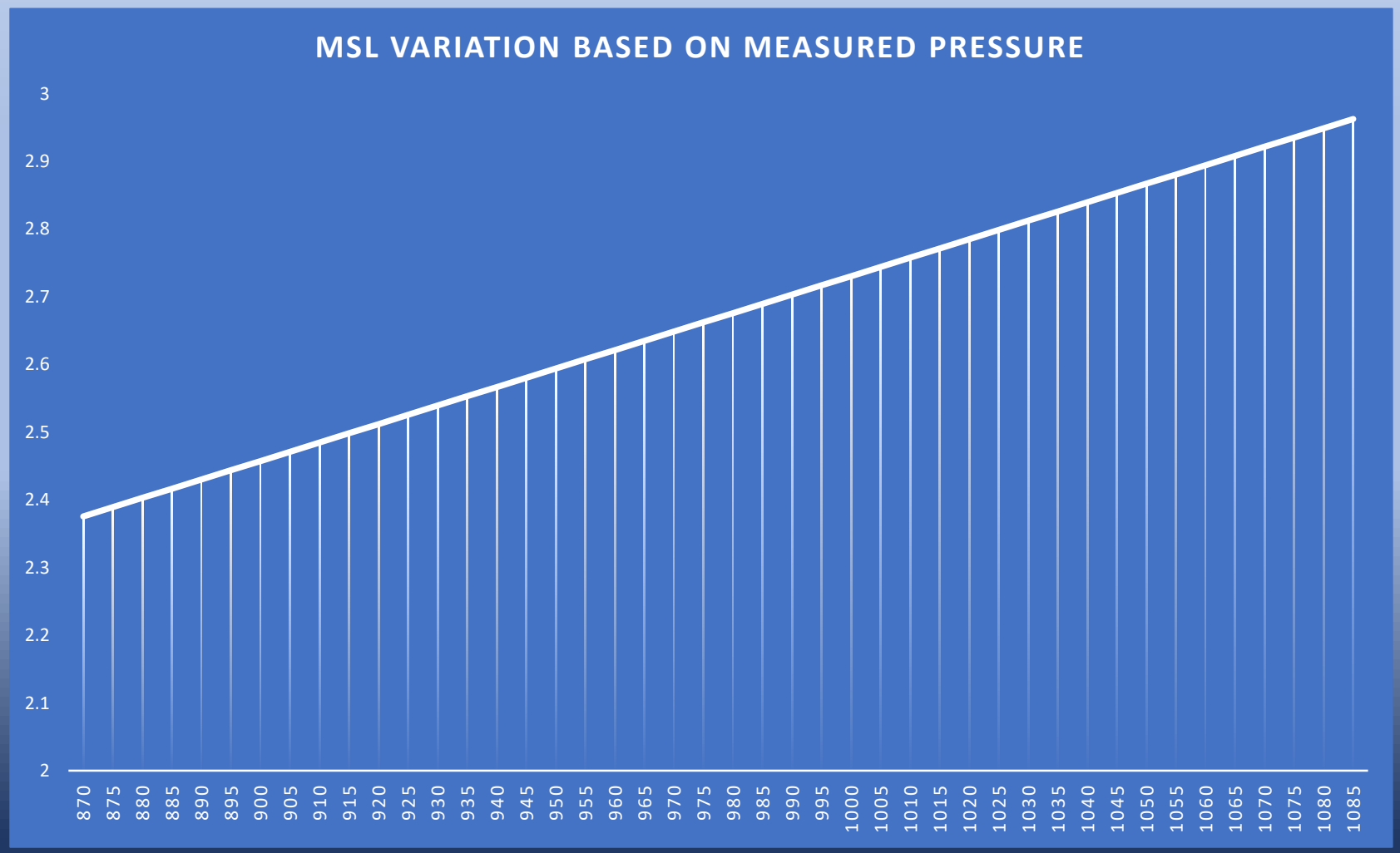
Change in MSL Vs Air Pressure



This graph sets the weather station height above MSL and with a fixed temperature. The sir pressure is varied to determine the difference in pressure between the weather station and MSL.

Height above MSL = 23 metres
Temperature = 15°C

The vertical Y-Axis is the increase in pressure (hPa) at MSL. The horizontal Y-Axis is the measured pressure at the weather station.

What Does It Mean?

- The Altitude graph shows that difference between MSL and measured atmosphere pressure can be significant, depending on the altitude of the weather station.
- The other graphs show that the variation in MSL pressure difference only changes slightly based on pressure and temperature variations.
- Since the changes because of current temperature and pressure so small, they can be ignored. For a home weather station, it is sufficient to calculate the MSL pressure difference once and apply it to all atmospheric pressures read by the weather station at that location.

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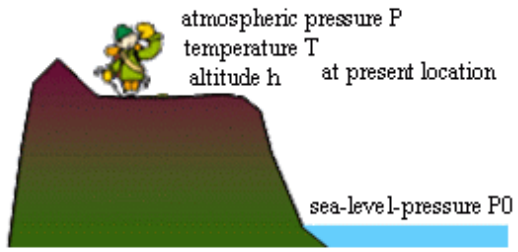
Calculating the MSL Pressure Difference

The atmospheric pressure shown on the weather map is adjusted to the equivalent sea level pressure.
(1atm=1013.25hPa)



at present location:

Altitude h	23	m
Atmospheric pressure P	1013.25	hPa
Temperature T	15	°C

Execute Clear Store/Read 14dgt

Sea-level pressure P_0	**1,016.02**	hPa
=	**1.0027**	atm

Sea–level pressure

$$P_0 = P\left(1 - \frac{0.0065h}{T + 0.0065h + 273.15}\right)^{-5.257}$$

- Find the height of your weather station by finding the height of the location above MSL using Google Earth or similar. The altitude at my house is 22 metres above MSL.
- Add the height of the sensor that measures atmospheric pressure. Usually, this is in the unit that measures the temperature in the house. This is about 1metre high above ground level in my house, giving a total of 23metres above MSL.
- Use an on-line calculator to work out the MSL pressure and subtract your starting pressure to get the difference and set your weather station.

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Thank You
For
Your Attention